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PRE-MILLING FLEXIBLE FIXTURE REVIEW AND OPTIMISATION

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ABSTRACT Machining requires correct workpiece location and restriction. Fixtures secure the workpiece for reproducibility, uniformity, and accuracy. The Workpiece Fixture System (WFS) minimises workpiece elastic deformation to improve machining quality. Elastic deformation impacts workpiece shape and precision. The workpiece's elastic deformation prevented even the most exact machinery from tightening tolerances. Deformation prediction and optimisation require much study. Batch or large production WFSs involve workpiece and fixture setup for machining. Fixture layout design (FLD) involves strategically placing locators and clamps around a workpiece to optimise machining and reduce machining forces. The right FLD holds the workpiece against cutting forces, minimising elastic deformation. FLDs depend on proper locator and clamp placement. FLD optimisation in WFS is essential for high-quality, low-cost machining.

I. INTRODUCTION

Fixtures are crucial to component manufacture. Fixture design must be precise to preserve component dimensions and shape throughout machining. Fixtures locate and limit the workpiece for precise machining. Fixtures provide component precision, dependability, and adaptability. Reduced setup times and fewer skilled operators boost production efficiency.

The WFS helps batch process identical workpieces. WFS uses several locators and clamps to secure the workpiece. FLD involves arranging clamps and locators on a workpiece. Minimising workpiece elastic deformation during machining with an efficient FLD ensures component quality. Machining fixtures contain the fixture body, locators, and clamps. The fixture body, which supports the fixture arrangement, holds the machined item. Locators and clamps secure it to the machine bed. Clamps match machining forces to hold the workpiece against the locators. Locators identify the workpiece's machine tool position.

All products require turning, facing, milling, etc. The finished product may contain faults. These issues are questionable. Machined components will not fit the design geometrically due to these defects. Multiple mutations in the same place increase rejection. Manufacturing still faces basic issues including poor product quality and high rejection rates due to faulty components. Form error, also known as shape error or geometrical mistake, occurs when a component's geometric form differs from its manufacturing shape (Lange 1985). Workpiece elastic deformations cause most part inaccuracies (Abdullah et al, 2011). Cutting or clamping stresses warp material. The machining operation will fail and create scrap if the dimensions and shapes are beyond the allowed range. Consistent component shapes and high precision necessitate dependable machining procedures (Wan Min et al., 2005). Machining fixtures help align and clamp workpieces. Fixtures retain pieces during machining and assembly. Milling requires a work holding fixture to accurately place and limit the workpiece. This device positions and aligns a workpiece during cutting. Clamps and locators are machining fixture staples. Clamps, unlike locators, are active fixtures that provide clamping pressure to the workpiece to resist machining forces. Trial and error and skill determine the ideal clamping, locating, and clamping force. Adjust clamping pressures freely to avoid component slippage. Clamping force selection may cause workpiece deformation, poor dimension and form accuracy, and fixture element mislocation (Wang et al., 2005).

II. THE FUNCTION OF FITTINGS

Fixtures are used to provide a secure mounting point for workpieces, providing support during operations and enhancing the quality, accuracy, and interchangeability of the finished products. It helps cut down on work time by facilitating fast set-up and a seamless flow from one segment to the next. It typically simplifies a procedure, enabling untrained employees to carry it out, and essentially passing the toolmaker's expertise to the worker. Fixtures can improve worker security by lowering the mental and physical demands of holding a workpiece in place. One of a fixture's most important economic roles is to lessen the need for human labor. Fixtures may be used to reduce the number of people needed to operate a machine or process from three to two by holding the workpiece in place. In Figure 1.1, the fixture is shown alone and then with a workpiece.

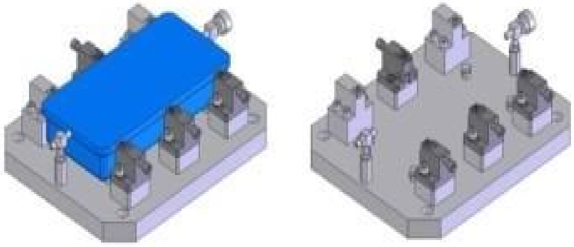

Figure 1 Typical fixture with workpiece

TYPES OF FIXTURES

The light fixtures are categorized by function. The following are some frequent uses for the categories listed. There are five main categories of lighting:

Fixtures made from a plate and various locators, supports, and clamps are known as "plate fixtures." Because of its adaptability, universal fixtures are the most often used kind of fixture. Depending on the component and the machining method, they may be fabricated from a wide variety of materials.

A variant of plate fixtures, angle-plate fittings have a reference surface that is perpendicular to the mounting surface rather than parallel to it.

Fixtures for vises, also known as vise-jaws, are customized inserts for vises made to hold a certain kind of workpiece. These light fixtures are the most budget-friendly and versatile. These fixtures are restricted only by the part's size and the capabilities of the available vises.

Indexing fixtures are used to locate features on a workpiece that have to be machined at a certain distance from one another. Fixtures used for indexing must provide a reliable way to find and keep the component in its indexed location.

Fixtures with multiple workstations allow for simultaneous machining of several components or for sequential machining of individual components using a variety of operations at each workstation. Fixtures may be categorized not only by their fundamental structure, but also by the process or machine tool they will be utilized with during machining. These are the most common kinds:

Milling Fixtures - Standard vises and clamps are examples of milling fixtures. However, the sophistication of the fixture increases in tandem with the work piece in terms of size, form, and intricacy. Commonly employed on horizontal machining centers, tombstones may store several pieces on up to four sides of the fixture and come in a wide range of forms. When it comes to holding work and fixturing devices for machining, nothing beats the t-slots of the machine table, which are uniform in size and spacing. Clamps, straps, t-slot bolts, nuts, and jacks are just some of the common accessories used to secure fixtures to the table.

Fixtures for lathes, also known as turning fixtures, follow the same fundamental design principles as milling fixtures with one key exception. While the component is rotated in the case of turning, the cutting tool is always rotated in milling operations. Because of this, the designer of the instrument must also account for centrifugal or rotating forces. Two or more join chucks of varying sizes and configurations are used in work-holding devices. The term "between centers" refers to holding the work between the lathe's head and tail stocks.

We recommend thinking about grinding fixtures not as a singular group but rather as a family. Surface grinding fixtures and cylindrical grinding fixtures are the two most common types of grinding equipment. When it comes to surface grinders, the magnetic table is the tool of choice for holding work pieces. Grinding a cylindrical object is often done after the turning process has been completed. In many cases, grinding a component that was previously turned between centers may make use of the same center holes. Fixture design should allow coolant flow and scrap removal since friction is more of a role in grinding than in other operations. The ability to dress the grinding wheel is a need that must be taken into consideration during fixture design.

Fixtures for Broaching The purpose of the broaching fixture is to retain and position the component in relation to the broaching tool. Different approaches to design are required for internal and exterior broaching. Since the internal broaching procedure seems to maintain the item securely seated on the fixture, less clamping is required. For external broaching, the workpiece must be fixed in a way that resists both the pull and puss pressures applied to it.

III. BACKGROUND WORK

DeMeter et al. (2001) developed a linear programming (LP) model to estimate the lowest clamping stresses that prevent slippage at the fixture-workpiece contacts during machining.

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We presume the fixture-workpiece system does not evolve as we machine.

Using a contact stability index sensitivity matrix, a variant of the friction cone concept, Kang et al. (2003) calculated the required clamping forces. **Meyer and Liou (1997)** provided an LP model that discretizes time-varying machining loads such that they may be analyzed using quasi-static techniques. **Xiong et al. (2003**) presented the clamping optimizations problem as a constrained nonlinear programming problem based on the concept of passive force closure.

To determine the minimum clamping force necessary to keep the workpiece in static equilibrium during machining, **Li et al. (2000)** reported a model that calculates the reaction forces and moments at the fixture-workpiece contacts. Scholars have suggested the notion of dynamic clamping to take into consideration the time-varying nature of the machining loads, including Wang et al. (1999), Tao et al. (1999), and Liu and Strong (2002, 2003).

By fine-tuning the clamping force, **Huang and Wang (2004)** were able to minimize static elastic deformation of the workpiece. In order to minimize distortion in the workpiece, Nee et al. (2000) proposed a sensor-aided fixture that could apply varying clamping loads as indicated by a quasi-static model. Other objectives may also be served by optimizing the clamping force. For instance, Hurtado and Melkote (2002) presented a multi-objective nonlinear optimizations model to determine the minimum clamping loads required to achieve workpiece shape conformability and fixture stiffness requirements.

Wang (2002) used a configuration matrix to describe the relationship between the workpiece's localization error and the changes in the location of the fixture's elements. Then, the matrix's critical characteristics were used as pointers to focus in on the optimal locator configuration for minimizing geometric variations at the most critical locations of the machined features.

Kulankara et al. (2002) employed GA to optimize fixture placement and clamping force, which decreased the workpiece's static deformation. To reduce workpiece deformation and variation, Liao (2003) employed the GA to figure out where and how many locators and clamps should be used during a sheet metal assembly.

IV. IMPORTANCE OF THE CURRENT STUDY

The efficiency and quality of the output are both affected by the fixtures' design. Fixture costs typically account for 10%-20% of the overall manufacturing cost in any batch production setting. The success of the fixture design process at now is entirely dependent on the designer's abilities. Manual design has poor dimensional and form accuracy because of inaccurate prediction of component stability against machining forces and workpiece deformation characteristics. Clamping pressures are often selected excessively to assure stability, leading to increased workpiece deformation during machining.

Due to elastic deformation resulting by inadequate fixture design, the high-precision machine was unable to impart the desired dimensional accuracy to the components. The elastic deformation also depends on the clamping force and the location of the fixturing devices used in the machining process. As a result, the elastic deformation of the workpiece may be reduced, and the precision of the machining can be enhanced by optimizing the fixture design parameters.

Elastic deformation must be considered and kept to a minimum when milling components that need micron-level tolerances for specialized uses. In such a situation, optimizing the factors responsible for elastic deformation is essential. When producing components with very tight tolerances, where carelessness leads to increased time and material waste, the current study subject will undoubtedly play a crucial role.

Slot milling and pocket milling are two examples of milling techniques studied here, and elastic deformation for each was minimized by shifting the positions of fixturing parts as much as was practically feasible. Experimentation has yielded the machining forces needed for modelling and analysis. Using evolutionary algorithms like GA, FA, and a hybridization of ANN-GA, the fixture arrangement has been optimized. Deformation as a function of tool route has also been studied and shown for two distinct milling processes. The next parts of this chapter discuss the research strategy and then outline the structure of the thesis.

Research Strategy

There are two main phases to this study, the first dealing with the modelling of WFS and the second with the optimization of FLD using different modelling methodologies and algorithms. Milling procedures like Slot Milling (SM) and Pocket Milling (PM) using an end mill cutter have been modelled with WFS and optimized with FLD. Workpiece deformation as a function of tool path and coefficient of friction is discussed. Figure 1.3(a) & (b) is a flowchart depicting the entire study strategy. Below is a summary of the steps in the flow diagram and the corresponding tasks.

Parameters Taken as Input

Workpiece geometry, component machining features, setup plan, fixture plan, machining forces, and tool path are only some of the inputs used to construct the Free Body Diagram (FBD) used by the WFS.

Input into the modelling process is provided by the workpiece's geometry. Since most of the components here are cut from prismatic bar on a VMC, the prismatic bar itself serves as the modelling material.

Some examples of machined component features include slots, pockets, and drill holes. The completion of a component may require several of these machining steps.

The setup plan details how the workpiece will be positioned in relation to the machine and what operations will be carried out. Additional surface machining on the component calls for a new setup method. As a result, there has to be a wide range of configuration strategies, each optimized for a distinct group of activities and their particular focuses.

The fixture plan is followed for each and every one of the many setup plans. The machining process begins with the workpiece being set up with the appropriate number and positioning of locators and clamps.

The machining forces have a significant role in defining the quality of the finished product. The fixture is meant to secure the workpiece in place during the machining process. In the present research, it is utilized to optimize FLD and simulate WFS using empirically determined SM and PM values. Discrete load increments are applied at numerous locations along the tool path to model the machining force.

Deformation of the workpiece, and thus the quality of the component, is also affected by the tool's route during feature machining. A variety of tool path techniques are accessible to the tool designed for use with any machining feature.

CONCLUSION

There has been an accumulation and categorization of literatures about the fixture layout design and optimization. In each section, the most important findings from the available research are summarized. Both the research gap analysis and the work's intended outcome have been outlined here. Subsequent chapters detail the various WFS modelling approaches, FLD analyses, and evolutionary algorithm assisted FLD optimizations. In order to manufacture a machined component with the necessary shape and size accuracy, it is important to minimize the elastic deformation of the workpiece. In this research, CAD was used to develop a method for optimizing fixture placement and clamping force. It improved the dimensions and shape correctness of the machined part by decreasing the amount of elastic deformation introduced into the part during the machining process. The authors of this research try out a variety of configurations, each with a different number of locators and clamps, to see which one best reduces workpiece distortion.

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